BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 10035

SUBJECT: Corona in LM Communication Equipment - Case 320

DATE: October 13, 1969

FROM: W. J. Benden

## ABSTRACT

The corona problems experienced in the LM S-Band Power Amplifier and Transceiver are discussed, including the present status of these units. Recent test results pertaining to corona problems in the LM VHF Transceiver are also reviewed. The solution for the corona problem with the LM S-Band Power Amplifiers and the S-Band Transceivers has been to mount them in pressurized cases. All the units for Lunar Modules through LM-15 have been delivered in this configuration.

The nature of the corona problem with the LM VHF Transceiver is still not clear. The results of recent tests which are now being analyzed should help to resolve this question.

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MEMORANDUM FOR FILE

## I. INTRODUCTION

It is well known that the LM communication equipment was originally designed to operate in atmospheric pressure or in a hard vacuum and at the LM-1 CARR, a review of the aft equipment bay pressure profile showed that the combination of leakage from the cabin and the thermal blanket resulted in significant pressures in the aft equipment bay. Subsequent testing of the communication equipment revealed corona problems in the S-Band Transceiver, S-Band Power Amplifier, and VHF Transceiver at partial pressures. Complete equipment redesign was essentially out of the question since delivery schedules had to be met and, of course, cost would be high. Consequently, many quick-fixes were tried -- many failed.

The author became familiar with the many problems involved, solutions tried, and the degree of the success obtained at a corona meeting called at Raytheon in November, 1967. Representatives from Motorola (S-Band Transceiver), RCA (VHF Transceiver), and Raytheon (S-Band Power Amplifier) presented the problems they had experienced at this meeting. Since then, the author has attended many meetings and witnessed many tests relative to corona in LM communication equipment.

The purpose of this memorandum is to briefly show the history and status of the corona problem in the LM communication equipment. To do this, November, 1967, is taken as a reference point.

The problem of corona in the VHF Transceiver is treated in a little more detail since this problem has not been completely resolved to date.

## II. S-BAND CORONA PROBLEMS

Figure 1 illustrates where corona problems have existed in the LM S-Band communication equipment. As of November, 1967, the multiplier chain in the transceiver and the power supplies and circulator in the power amplifier were exhibiting corona failures. The various fixes tried (primarily potting fixes) were not successful. Motorola had completed some work on the design and construction of a pressurized case which would completely enclose the S-Band Transceiver. Raytheon felt that further work in the potting-fix area would solve the power supply problem of the S-Band Power Amplifier. The circulator had already been redesigned to remove its corona problem. Raytheon agreed to follow a back-up approach which involved the design of a pressurized case for at least the power supply.

In April, 1968, RCA directed Motorola to implement the pressurized case for the S-Band Transceiver and as of February, 1969, all transceivers had been tested and delivered without any evidence of corona.

In May, 1968, Raytheon was directed to cease effort on the pressurized case design for the S-Band Power Amplifier (PA) since the potting-fix, with some redesign, had apparently eliminated corona in the power supply. However, in August, 1968, the amplitron tubes in the PA started to fail during thermal vacuum testing. Failures were traced to the high voltage leads within the outer case of the amplitron as shown on Figure 2 (Areas A, B, and C). Since failures had taken place in an area where the leads were potted in silicone rubber, several tubes were dissected to investigate the possibility of voids since the tubes were potted at atmospheric pressures. Voids were found and calculations on the amount of time required for a void to lead down to a critical pressure region indicated approximately 300 hrs.as the worst case. (Figure 9 illustrates how voltage breakdown varies with pressure).

In November, 1968, it was decided that the work on the power amplifier case pressurization design, which had been terminated, should be resumed. A test program was also initiated to gain confidence in the power amplifier. Part of the test program would involve testing reject amplitron tubes for corona over an Apollo mission-type vacuum profile. These tubes had been rejected for reasons other than corona and, of course, were available. Figure 3 shows the basic test plan to be followed. Figure 4 provides a very brief summary of the test results, and Figure 5 singles out the test results obtained on eight reject tubes.* The corona inception level was

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*Tubes were tested in groups of eight. Time scheduling prevented corona testing of the first set of eight tubes. In fact, the second set was not implemented until about four days into the test.

measured by gradually increasing the tube voltage (tube not operating) until corona was noted on an oscilloscope.

In January, 1969, Raytheon was directed to implement a pressurized case for the S-Band Power Amplifier and to install new circulators in the process. As of September, 1969, all S-Band Power Amplifiers had been built, tested, and delivered with no corona problems evident. The total number of units completed is sufficient to provide equipment through LM-15, plus two ERA spares and one module spare (components at sub-assembly level). This applies to both the S-Band Transceiver and S-Band Power Amplifiers.

## III. VHF TRANSCEIVER CORONA

Corona problems in the VHF Transceiver had apparently been solved (as of November, 1967) by installing teflon baffles between the vulnerable components as shown on Figure 6. Subsequently, RCA pursued a crash program to add a VHF ranging capability to the transceiver. In March, 1969, Mr. Pajak of NASA/MSC sent the author the data given in Figure 7 and asked for an opinion on the possibilities of corona still remaining in the VHF Transceiver. In the writer's opinion, no conclusion could be drawn since both pressure and temperature were varied simultaneously. By early May, 1969, thermal vacuum testing on SN-113 was underway at RCA. After reviewing data from these tests, the author concluded that the variations on Figure 7 were due to temperature and inaccuracies in instrumentation set-up.

During the May 7, 1969, test, the power output of transmitter "A" suddenly dropped to about one-half its normal value. In the subsequent switching, cable changing, etc., the power of transmitter "A" returned to approximately its normal value. The author then recommended that the pressure be gradually increased and then decreased to see if the phenomenon would repeat. Figure 8 shows this recycle of pressure and the sequence of events which followed. A new attenuator was installed for transmitter "B" when problems were noted for a pressure near $10^{-3}$ Torr, but transmitter "B" showed further power changes as the unit was being brought up to atmospheric pressure. Additional details of these tests are included in RCA Test Report, "Substitute Thermal-Vacuum and Corona Tests LM VHF Transceiver Assembly," LTR-P-4270-7, 28 May 1969. Following the thermal vacuum testing of SN-113, the unit was disassembled to a level where most of the components could be seen. The author personally examined every accessible component under a microscope and could find no <u>positive</u> evidence of corona. The author then asked Mr. R. Lang of Bell Laboratories to also examine SN-113 and his conclusions were the same. Other representatives present also examined the components with negative results. Of course, corona could have occurred in several areas where disassembly was not practical. Additional vacuum tests were performed on SN-113 at the module level with no indication of corona.

VHF Transceiver SN-111 was then tested over a similar vacuum profile and it exhibited power changes which could be attributed to corona.

During a meeting on corona at RCA on June 25, 1969, comments were requested on the test results. The author stated that he had observed the various units, which had exhibited corona effects, tend to grow quiet as they approached pressures in the vicinity of $10^{-3}$ Torr and that during an actual lunar mission, the unit could very well be down in this region (see Figure 5) before the communication equipment was turned on. Of course, there still exists the possibility of individual components (resistors, capacitors, etc.) leaking slowly, but from previous testing the units appeared to be following the vacuum chamber pressure. It was also noted that in every case where the VHF unit exhibited corona effects, it recovered and provided its original power output. That is, the failures were never catastrophic.

The only positive way of removing doubt on slowly leaking components is to pressurize the entire VHF Transceiver. However, testing several units to a mission-type profile would give confidence that corona would not occur during the mission. During the period of August 10, 1969, through August 15, 1969, the author witnessed the testing of SN-127 and reviewed some of the test data obtained. Apollo 11 telemetry data was used by GAEC to up-date Figure 5 and the resulting vacuum profile used during testing. The unit was allowed to vacuum soak for 55 hrs. before equipment turn-on. The data reviewed showed no evidence of corona. Since then, similar tests have been performed on SN's 122 and 126. Data obtained from these units are being analyzed. A meeting will be held at RCA in early October to discuss data analyses and the benefits to be gained by testing the remaining units over a mission-type profile prior to delivery.

William J. Benden

2034-WJB-drc W. J. Benden

Attachment
Figures 1 thru 9

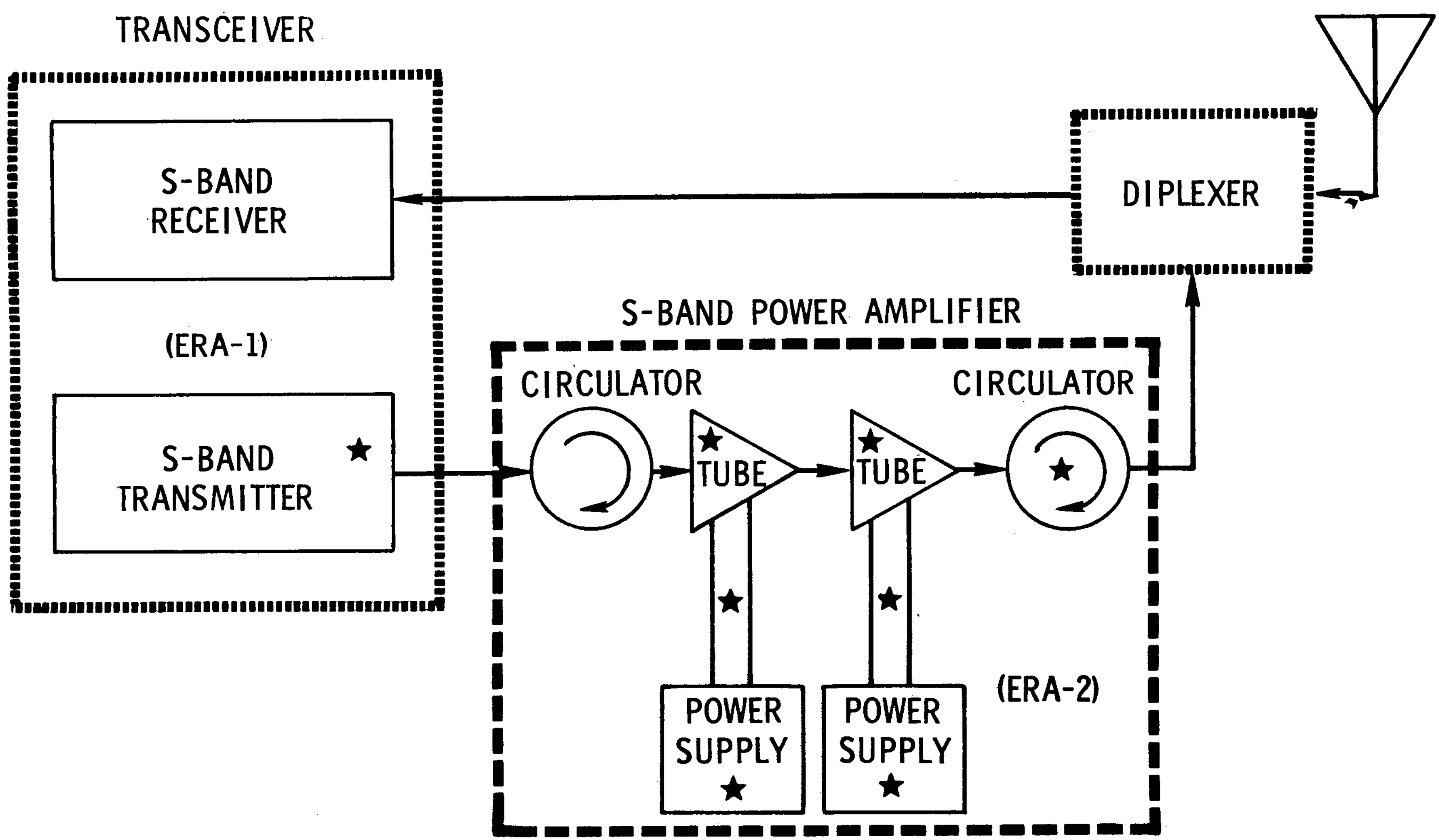



FIGURE 1 - LM S-BAND CORONA PROBLEM AREAS★
IN ELECTRONIC REPLACEABLE ASSEMBLIES (ERA)

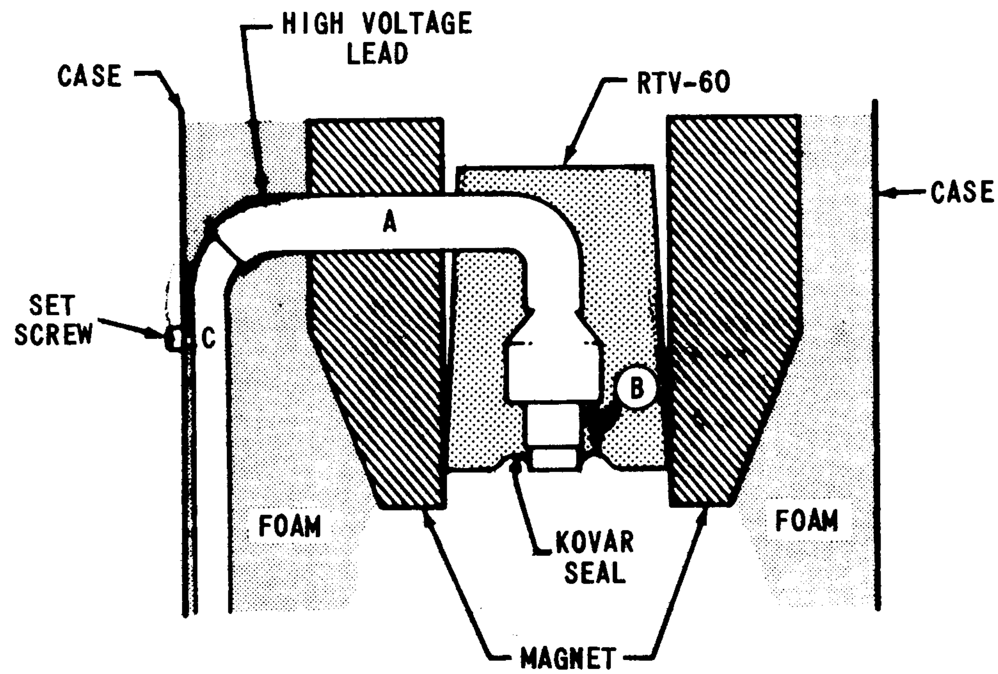



FIGURE 2 - ROUGH SKETCH SHOWING AREAS OF CORONA ARC OVER IN THE AMPLITRON OF THE LM POWER AMPLIFIER

AS A RESULT OF THESE AMPLITRON FAILURES (SN 258, 228, 200, AND SN 198) THE CCB AT MSC REQUESTED:

1) TESTS ON 16 REJECT TUBES IN EXTENDED THERMAL VACUUM

2) TESTS ON 2 REJECT TUBES AT VOLTAGES BEYOND NORMAL OPERATING LEVEL

3) TESTS ON 4 FLIGHT "ERAS" IN EXTENDED THERMAL VACUUM

4) RESUMPTION OF ERA CASE PRESSURIZATION WORK

5) BASED ON RESULTS OF ABOVE TESTING MAKE DECISION ON CASE PRESSURIZATION IN JANUARY 1969

FIGURE 3 - APPROACH TOWARD CORONA PROBLEM SOLUTION

- NO CATASTROPHIC FAILURES
- FIRST 8 AMPLITRONS:

    1) CHANGES IN CORONA INCEPTION LEVELS (PRE AND POST TESTS)
    2) CHANGES IN LEAKAGE CURRENTS (PRE AND POST TEST)
    3) CORONA MEASUREMENTS DURING VACUUM TEST NOT IMPLEMENTED

- SECOND 8 AMPLITRONS:

    1) CORONA MEASUREMENT MADE DURING VACUUM TESTS
    2) SIX OUT OF EIGHT TUBES SHOWED CORONA INCEPTION LEVELS WELL BELOW NORMAL OPERATING VOLTAGE

- FIRST 2 ERAS:

    1) ONE OUTPUT CIRCULAR FAILURE (CORONA-BUT UNIT RECOVERED)
    2) AM NOISE BEYOND SPECIFICATION
    3) PM NOISE BEYOND SPECIFICATION
    4) POWER SUPPLY VARIATIONS
    5) BURSTS OF NOISE ON RF OUTPUT

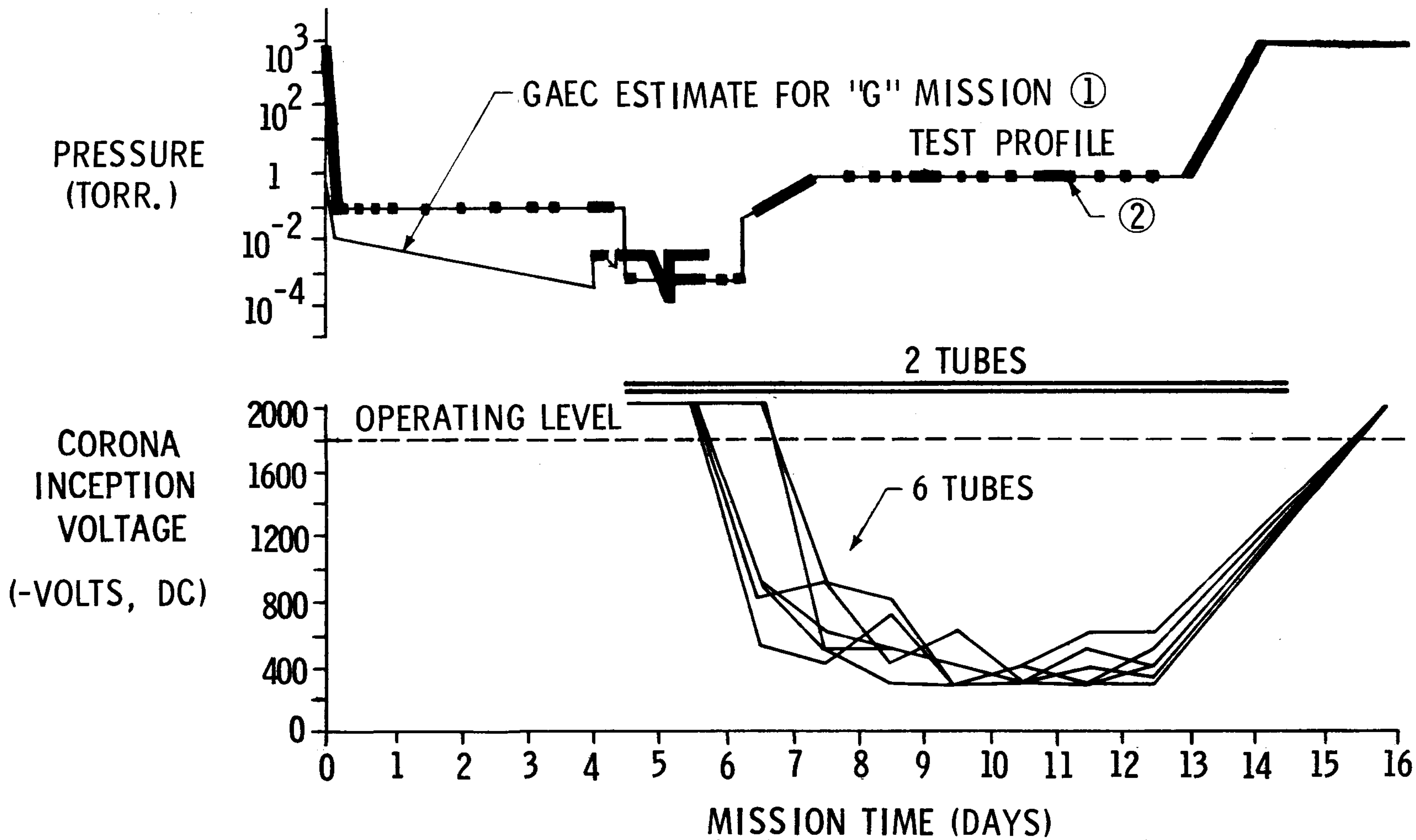
    (CORONA POSSIBILITIES)

- SECOND 2 ERAS:

    1) SAME AS FIRST 2 ERAS IN ITEMS 2, 4, AND 5

- VOLTAGE OVER-STRESS TESTS LIMITED TO PREVENT PERMANENT DAMAGE TO AMPLITRON TUBE

FIGURE 4 - BRIEF SUMMARY OF TEST RESULTS




① ESTIMATE NOT AVAILABLE AT TIME OF TESTING

② BROKEN HEAVY LINES REPRESENT AMPLITRON OPERATE TIME

FIGURE 5 - TEST SUMMARY OF 8 AMPLITRONS

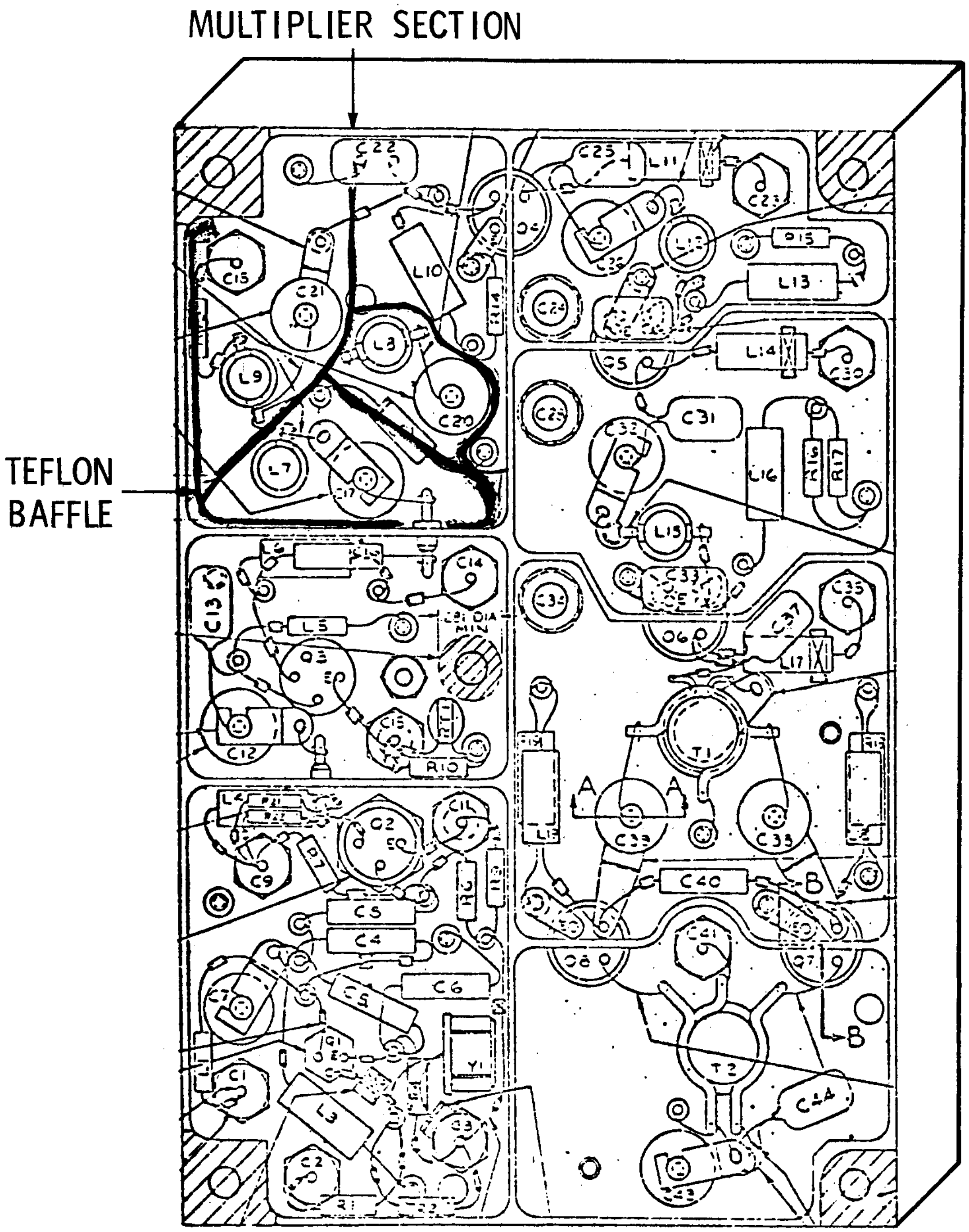
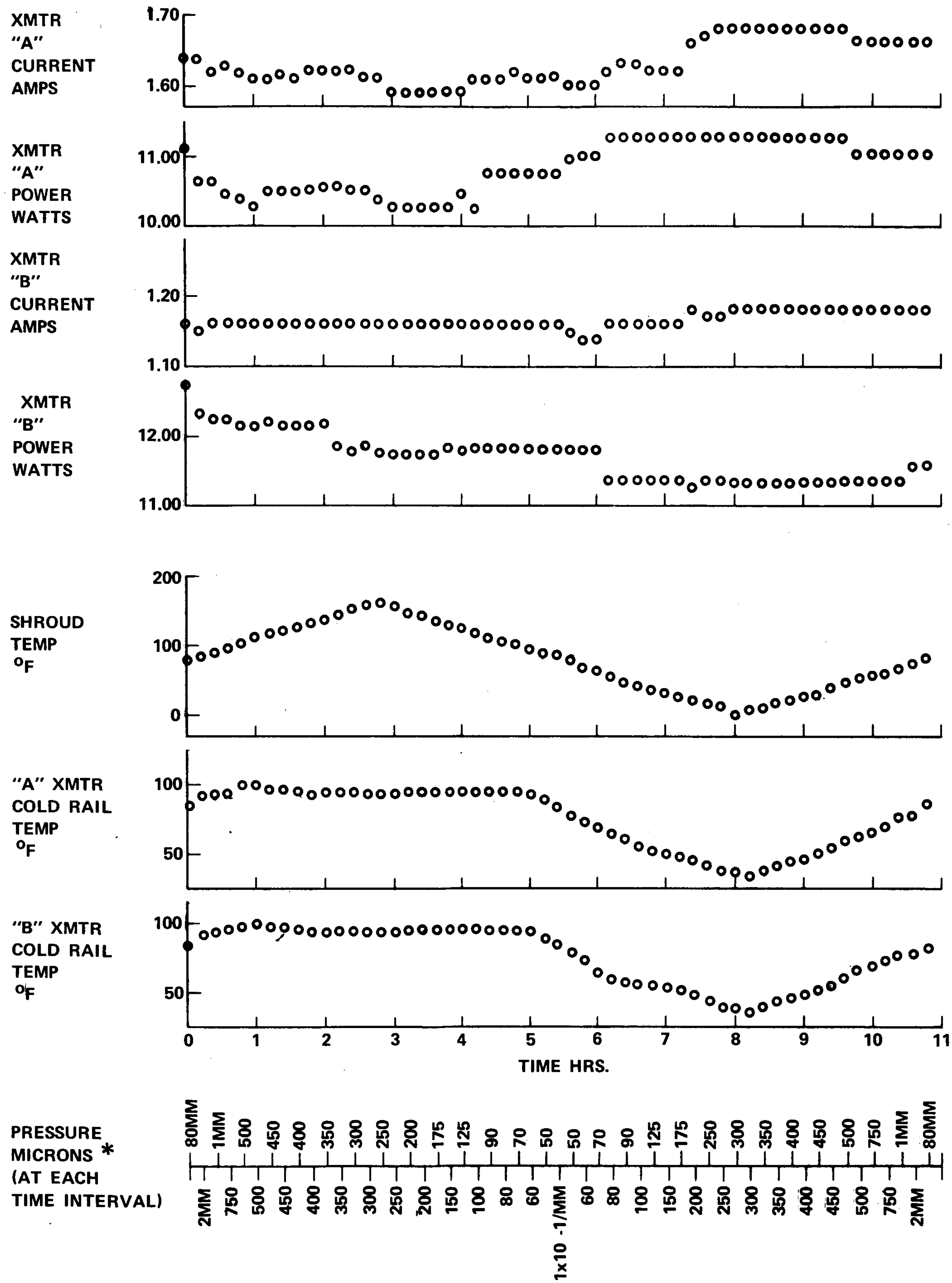



FIGURE 6 - TEFLON BAFFLES IN EXCITER POWER AMPLIFIER SUBASSEMBLY




* UNLESS INDICATED IN MM

FIGURE 7 - P III DELTA QUAL TEST RESULTS

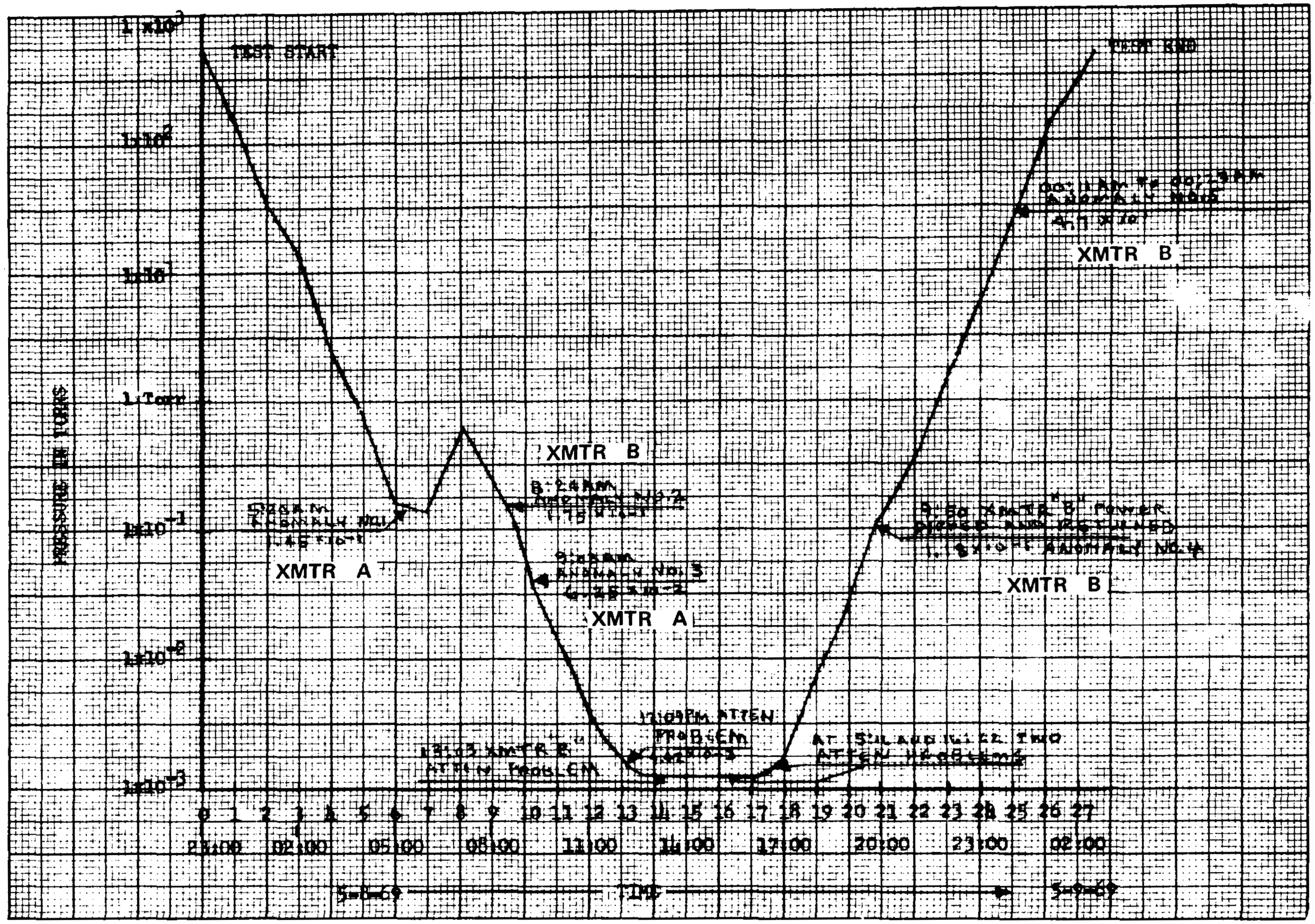



FIGURE 8 - PRESSURE VERSUS TEST TIME S/N 113

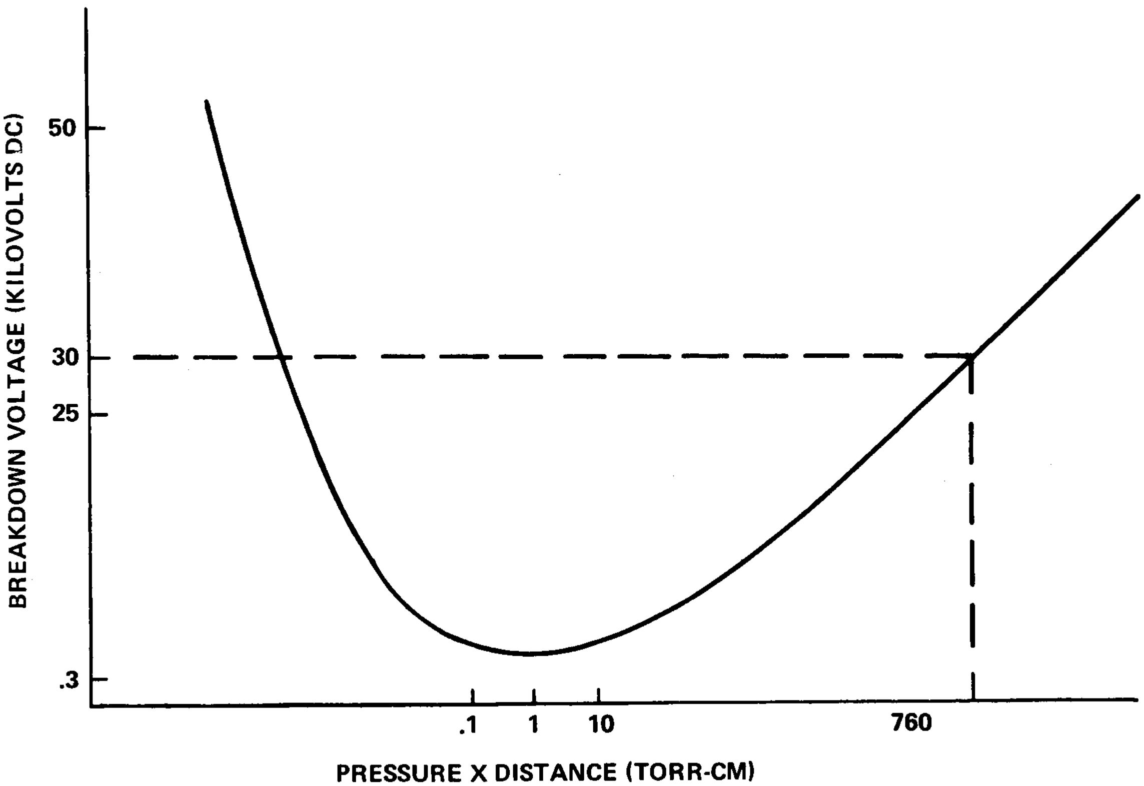



FIGURE 9 - PASCHEN'S CURVE OF SPARKING VOLTAGE AS A FUNCTION OF THE PRODUCT OF GAS PRESSURE AND ELECTRODE SPACING (UNIFORM FIELDS)

FROM " THE PREVENTION OF ELECTRICAL BREAKDOWN IN SPACECRAFT"
F. W. PAUL AND D. BURROWBRIDGE, GSFC REPORT: X327-69-75, DATED FEB. 1969

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